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ABSTRACT

The relationship between transformation problem performance and Guilford Structure of Intellect (SI) abilities is explored. During two group sessions 42 females and 35 males, age 18-39, were administered 12 Guilford SI tests exemplifying all five symbolic content (numeric) operations, and three contents in the divergent production area. Logical and general reasoning were included. Later, the same subjects employed a computer-controlled program to solve two tasks involving move strategies, the water jug problem (W-J) and the missionary-cannibal problem (M-C). A computer stepwise multiple regression program was run using the number of legal moves to solution as the dependent variable. Results indicated that the ability tests were intercorrelated, and significantly correlated with the W-J. General reasoning entered first and accounted for 32% of the variance for W-J, whereas number rules entered first and accounted for 10% of the variance for M-C. Males tended to perform better than females on the W-J, but both sexes performed similarly on the M-C. Because the same model cannot account for solving both tasks, analysis of tasks and student characteristics are necessary. (Author/RL)

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TRANSFORMATION PROBLEM SOLVING ABILITIES

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This research explores the relationship between transformation problem performance and Guilford Structure of Intellect (SI) abilities. 42 female and 35 male paid subjects attended 3 sessions: two group testing and a computer controlled problem solving. A stepwise multiple regression found the ability tests were intercorrelated, and significantly correlated with the water-jug. General Reasoning entered first and accounted for 32% of the variance; the subject who is better at understanding the task structure is better at solving water-jug problems. The task elicits all five SI operations. One test was correlated with missionary-cannibal. The same model cannot account for both problem solving tasks. Implications are that the teacher must analyze the task and student characteristics.

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TRANSFORMATION PROBLEM SOLVING ABILITIES

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A current topic in psychology and education is the nature of relationships between problem solving processes, abilities of the solver, and nature of the task (Resnick, 1976; Sternberg, 1977). The present research explores the relationship between performance on transformation problems and selected Guilford Structure of Intellect (SI) abilities.

The transformation problems are water-jug (W-J) and missionary-cannibal M-C). Both tasks have a specified goal, an initial situation, and a set of operations that produce changes in situations. A move or operator transforms one state into a new state. At each state there are a number of possible alternative moves. The solver cannot reach the goal in one move but must apply various heuristic strategies to choose a succession of operators until the goal is reached. For the naive solver, such strategies are likely to involve difference reductions. Models of processes have been developed for the transformation problems (Atwood and Polson, 1976; Jeffries et al., 1977) and include the means-ends analysis and a heuristic that avoids previously visited states. This study investigates the possibility that a solver who gives evidence of Guilford's (1967) divergent production abilities should also quickly produce alternate moves on a transformation problem, and probably choose those moves which lead closer to the goal rather than those considered earlier.

Another component of problem solving is understanding, building an internal representation of the problem (Hayes, 1978). Both prior knowledge and external stimuli may influence the encoding process. The task content may evoke one or more of the several representations available.

There is a large between subject variance, accounted for by the model by probabilistic choice processes. The parameters give a good fit to group data, with individual differences as random variations. An alternative explanation is that subjects don't start with identical cognitive skills. Correlational analyses can give an indication as to whether individual differences in abilities affect the solution process.

Previous research with water-jug problems has thus far found few correlations with ability tests. Masson (1977) found few relationships between memory factors and problem performance. Harmel (1977) found that the SI test Alternate Additions (Divergent Production of Symbolic Relations) was significantly correlated with water-jug performance; the other four tests did not. Divergent production processing may be used in performing the water-jug task; if so, a correlation should occur with most divergent SI tasks. If numeric content is the important aspect, then correlations should occur on tasks using numeric content across processes.

Logical reasoning and general reasoning have been found to be correlated with problem solving performance (Guilford, 1967). It is possible that cognition and evaluation operations are also involved in W-J performance. A number of Guilford tests will be given to subjects in addition to the W-J and M-C tasks. The latter does not have a highly numeric content. There may be one operation which accounts for much of the variance underlying either of the problem solving tasks. In particular, the divergent production operation may account for variation previously unaccounted for in models of transformation problems.

METHOD

Subjects. There were 42 females and 35 males recruited through a newspaper ad. Subjects were required to attend 3 sessions, and were paid $12.00 at the conclusion. Ages ranged from 18 to 39, average 23 years.

Test Materials. The first two sessions employed twelve Guilford SI tests. Tests exemplified all five operations in the symbolic content (numeric) area and three contents in the divergent production area. In addition, Logical Reasoning and General Reasoning were included. The abbreviation and SI designation is listed next to each test.

1. Symbol Manipulation (SM) (ESR: Evaluation of Symbolic Relations). Syllogisms test using numerical relations. Premises and conclusions are statements of equality and inequality. The subject judges several possible conclusions as true or false. One part.

2. Sign Changes (SC) (NSI: Convergent Production of Symbolic Implications). A deductions test where the subject solves simple math equations by replacing one of the operation signs with another. One Part.

3. Operations Sequence (OS) (NSS: Convergent Production of Symbolic Systems). Number test which requires the subject to arrange events temporally. Given one number, the subject applies in proper sequence three given operations in order to arrive at another number. One part.

4. GZAS Numerical Operations (NO) (NSI: Memory of Symbolic Implications). Simple problems of addition, subtraction, and multiplication in multiple choice items; subject must be rapid.

5. Number Series (NS) (CSS: Cognition of Symbolic Systems). Series extrapolation. The subject states the rule used to create the series. One part.

6. Alternate Additions (ADD) (DSR: Divergent Production of Symbolic Relations). Subject was given a series of numbers to add to a particular sum. Two parts.

7. Number Rules (NR) (DSR). Subject starts with a given number and must reach a second given number by applying a variety of mathematical operations. One part.

8. Match Problems (MP) (DFT: Divergent Production of Figural Transformations). Subject is presented with a number of adjacent squares or triangles, whose sides are matches. Subject removes a specific number of matches leaving a specified number of complete squares. Two parts.

9. Symbol Production (SP) (DET: Divergent Production of Semantic Transformations). The subject produces a figural representative for specified words in short sentences. The drawing is to impart the appropriate meaning. One part.

10. Expressional Fluency (EF) (DMS: Divergent Production of Semantic Systems). Subject is given four letters and must produce a variety of sentences in two minutes. Four parts.

11. Logical Reasoning (LR) (EMI: Evaluation of Semantic Implications). A syllogism test in which the subject is given two statements and four potential conclusions. Subject chooses the one which logically follows from the premises. One part.

12. General Reasoning (GR) (CMS: Cognition of Semantic Systems). An arithmetic reasoning test in which needed number computations are simple.

Problems: Two problem solving tasks were given during the third session, the water-jug problem and the missionary-cannibal problem. A two-path W-J presented three jugs: A, B, C; size (8, 5, 3). The largest jug A held 8 units of water. The subject must perform a series of pouring moves to reach the goal of 4 units in A and 4 in B. There were 16 possible states the goal could be reached by one of two paths. The minimum path was 7 moves. From each state the subject could move backwards, forward toward the goal, or loop back to one of four top states. Subjects who move or loop back solve the problem less efficiently.

The missionary-cannibal (hobbit-orc) task presented 5 hobbits and 5 orcs on the left side of the river together with a boat that would hold 3. The goal was to have all 10 critters on the right bank. There were 27 possible states; numerous early move possibilities, a mid-point one-path sequence, and again, numerous paths to reach the goal. The minimum path was 11 moves.

Some move strategies were less optimal than others and resulted in the subject looping around the paths. The number of possibilities varied with each state.

Procedure: There were three sessions occurring over a 5-day period. Sessions 1 and 2 were group testing and lasted approximately 1 1/2 hours each, 6 tests were administered in S1 and 4 tests in S2. Order was the same for all subjects. Guilford administration procedures were followed. The experimenter read the instructions with the subjects, allowing time for practice items and for questions. Each test was timed with a stop-watch; times ranged from 1 to 35 minutes. The third session presented the problem solving tasks by Zerox Sigma 3 computer. From 1 to 6 subjects were run concurrently. Presentation of instructions and problems was by a Fortran IV program using a CRT screen. Subjects responded by pushing buttons corresponding to problem elements. Subjects received water-jug instructions, a W-J practice problem (size (6, 4, 1) goal (3, 3, 0)) the W-J problem (size (8, 5, 3) goal (4, 4, 0)), hobbit-orc instructions, the H-O problem (5 each, boat size 3). Subjects who failed to solve this W-J problem in 100 legal moves were informed of the solution and allowed to go on to the H-O problem. The third session was individually paced; times ranged from 1/2 to 2 hours.

Results: The SPSS stepwise multiple regression program was run using the number of legal moves to solution as the dependent variable. The ability tests were highly intercorrelated. The majority of the tests were significantly correlated ($p < .01$, two tailed) with the W-J, whereas only NR significantly correlated with M-C (Table 1). For the W-J task, GR was entered first ($F=36.4$) and accounted for 32% of the variance. The remaining 12 ability tests had small F's(< 2), together accounting for an additional 8% of the variance. The order was: GR, LR, SP, NO, NR, SM, SC, NS, EF, MP, ADD.

The hypothesis that divergent production would account for a portion of the underlying variance was tested by entering those tests first, then symbolic content tests, and finally GR & LR. Divergent production accounted for an additional 8%, GR 10%, and LR 2%. For the M-C task, NR was entered first (F=8.6) accounting for 10% of the variance. SP accounted for 3% with the remaining measures accounting for 5%. The order was: NR, SP, ADD, EF, NO, SC, OS, LR, SM, NS, MP, GP. The relationships pattern for problem-solving was similar for males and females; performance did not differ on the M-C task: mean legal moves m=30.9, f=33.5. Males tended to perform better on the W-J task: m=22.0, f=32.5 (ANOVA F=3.4, p .068).

Conclusions: Unlike previous research mentioned earlier, the present experiment found numerous ability tests correlated with the water-jug problem. The large number of intercorrelations indicates that the W-J task is factorially complex. There were few correlations with the missionary-cannibal task. The Jeffries et al. (1977) model of transformation problems was hypothesized to account for both tasks. However the present results indicate that this is not the case.

The present results seem to indicate that in addition to the modeled processes of means-ends analysis and new-move neuristic, the W-J subject employs several other processes. The W-J task appears to require all five operations as hypothesized by Guilford's (1967) analysis of problem solving behavior. The main operation brought out in the present study is cognition (GR). The subject who is better at analyzing the situation and understanding the structure of the task will also be better at solving W-J problems. The operation measured by GR appears to be less relevant for solving M-C.

Divergent production appears to be relevant in both problems. The W-J task is more content specific; divergent production of figural and symbolic content is involved but not semantic content.

Missionary-cannibal seems to be less effected by differential evaluation and reasoning abilities. These results match newer Colorado models (Polson, personal communication) of M-C and tower of hanoi tasks. The move selection process is triggered by the subject's immediate perception of the display. Several moves are seldom evaluated. The older model continues to suffice for water-jug problems. Subject's behavior is more conscious; the solution includes a serial evaluation of moves. Thus transformation problems require more than one model, and each model must incorporate more than one process.

Implications for education are those mentioned by this author at the 1978 AERA meeting: the teacher must analyze the task and student characteristics. For instance, students will not perform well on tasks such as W-J if they are deficient in working with numeric symbols. Students could be taught to quickly analyze and evaluate the situation. However such training will not transfer to all problems (see also Jeffries, 1978). Finally, males and females seem to perform similarly.

TABLE 1

		WATER-JUG	HOBBIT-ORC
GUILFORD SI ABILITY TEST	SM	-.29*	-.13
	SC	-.22	-.21
	BS	-.34*	-.13
	NB	-.32*	-.11
	NS	-.43*	-.16
	NR	-.33*	-.32*
	ADD	-.37*	-.22
	MP	-.32*	-.14
	SP	-.01	-.13
	EF	-.02	-.14
	LR	-.38*	-.20
	GR	-.57*	-.22

Correlations of Ability Tests and Transformation problem:legal moves to solution

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